Searches for Contact Interactions at HERA

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The H1 and ZEUS collaborations at HERA have searched for signatures of physics beyond the Standard Model with high Q^2 neutral current deep inelastic electron-proton and positron-proton scattering events. No significant deviations from Standard Model predictions were observed. Various *eeqq* contact interaction models have been considered. Limits on the compositeness scale in general *eeqq* contact interaction models, mass to the Yukawa coupling ratio for heavy leptoquarks, the effective Planck mass scale in models with large extra dimensions and the effective quark charge radius are presented.

1 Introduction

The H1 and ZEUS experiments at HERA (DESY, Hamburg) allowed the study of electron-proton and positron-proton collisions at center of mass energies of up to 920 GeV. During the so called HERA I running phase (1994-2000) about 100 pb^{-1} of data were collected per experiment, mainly coming from e^+p collisions. After the collider upgrade in 2000-2001, resulting in a significant increase of luminosity, about 400 pb^{-1} of data per experiment were collected in the so called HERA II phase (2002-2007). Moreover, spin rotators installed at the H1 and ZEUS interaction regions provided longitudinal electron and positron polarization. With average lepton beam polarization of about 30-40% and significant increase of integrated data luminosity (especially of collected e^-p sample) HERA II has significantly increased the sensitivity of the experiments to physics beyond the SM.

2 Contact Interactions

New interactions between electrons and quarks involving mass scales above the center-of-mass energy can modify the deep inelastic $e^{\pm}p$ scattering cross sections at high Q^2 via virtual effects, resulting in observable deviations from the Standard Model predictions. Four-fermion contact interactions are an effective theory, which allows us to describe such effects in the most general way. Vector *eeqq* contact interactions considered at HERA can be represented as an additional terms in the Standard Model Lagrangian:

$$L_{CI} \;=\; \sum_{i,j=L,R} \eta_{ij}^{eq} (\bar{e}_i \gamma^\mu e_i)(\bar{q}_j \gamma_\mu q_j)$$

where the sum runs over electron and quark helicities, and a set of couplings η_{ij}^{eq} describe the helicity and flavor structure of contact interactions. Various scenarios, with different chiral structures, were considered by H1 and ZEUS. Limits on the model parameters were derived from the analysis of neutral current deep inelastic scattering (NC DIS) events. Details of the analyses are described in [2, 3].

3 Results

In the general case (also referred to as compositeness models), limits on the effective "new physics" mass scale Λ (compositeness scale) are extracted assuming the relation $\eta = \pm 4\pi/\Lambda^2$. Figure 1 shows the results obtained by the ZEUS for different compositeness models, based on the analysis of 1994-2006 data. Limits on the effective mass scale Λ range form 2 up to 8 TeV. Corresponding limits obtained by the H1 collaboration, based on the HERA I data only, range from 1.6 to 5.5 TeV [2].

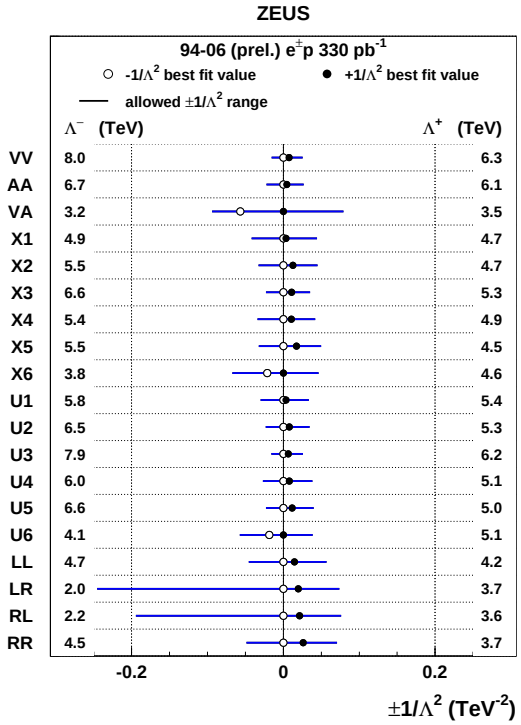

Figure 1: Results for general contact interaction models (compositeness models) obtained using the combined e^+p and e^-p data from ZEUS (1994-2006). Horizontal bars indicate the 95% CL limits on $\eta/4\pi = \varepsilon/\Lambda^2$; values outside these regions are excluded. $\Lambda^{\pm}$ are the 95% CL limits on the compositeness scale for $\varepsilon = \pm 1$.

For the model with large extra dimensions [4] both collaboration set limits on the effective Planck mass scale M_S. For negative coupling sign scales below 0.90 TeV (ZEUS 1994-2006) and 0.78 TeV (H1 1994-2000 [2]) are excluded on 95% CL. For positive couplings the limits are 0.88 TeV and 0.82 TeV respectively. Possible effects of graviton exchange on the Q^2 distribution of NC DIS events, as measured by ZEUS, are shown in Figure 2.

Also, searches for possible quark substructure can be made by measuring the spatial distribution of the quark charge. By using the "classical" form factor approximation, and assuming that both electron and exchanged bosons are point-like, limits on the mean-square radius of the electroweak charge of the quark can be set. From the analysis of combined

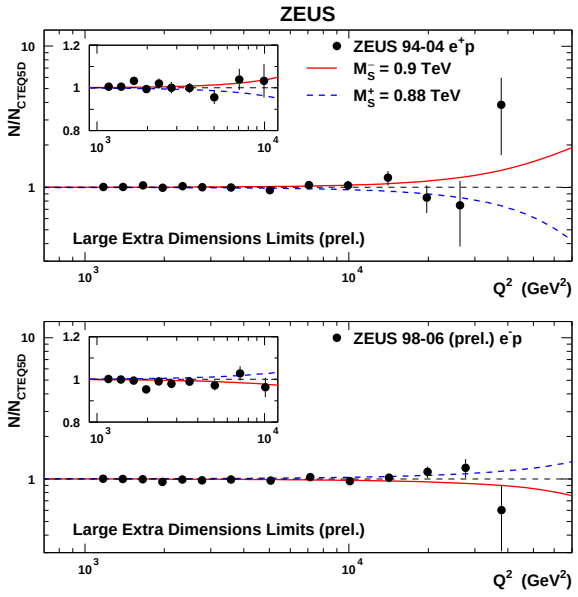

Figure 2: ZEUS data compared with 95% CL exclusion limits for the effective Planck mass scale in models with large extra dimensions, for positive (M_S^+) and negative (M_S^-) couplings. Results of the experiments are normalized to the Standard Model expectations using CTEQ5D parton distributions.

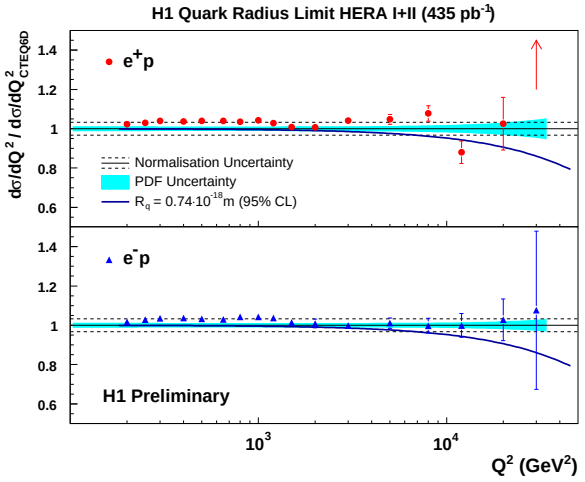

Figure 3: H1 data compared with 95% CL exclusion limits for the effective radius of the quark [5]. Results of the experiments are normalized to the Standard Model expectations using CTEQ6D parton distributions.

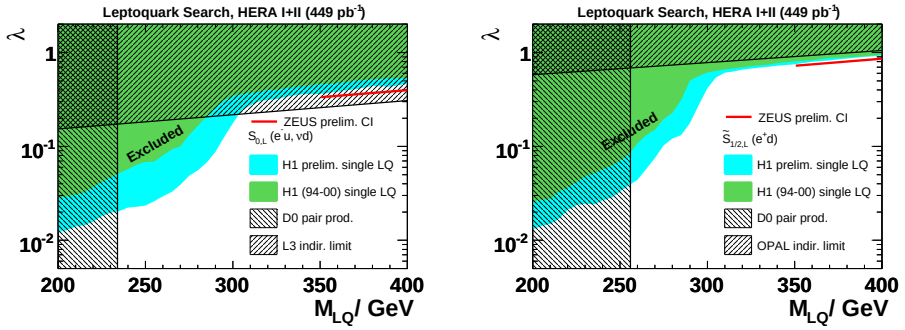

Figure 4: H1 exclusion limits at 95% C.L. on the coupling as a function of the leptoquark mass for $S_{0,L}$ and $\tilde{S}_{1/2,L}$ leptoquarks [6]. The indirect limits from ZEUS and L3 and the direct D0 limits are shown for comparison.

HERA I and HERA II data quark radii bigger than $0.74 \cdot 10^{-16}$ cm (H1) and $0.62 \cdot 10^{-16}$ cm (ZEUS) have been excluded at 95% CL. Figure 3 shows the H1 data together with 95% C.L. exclusion limits for the effective radius of the quark [5].

Contact interactions can also be used to describe the effects of virtual leptoquark production or exchange at HERA, in the limit of large leptoquark mass $M_{LQ} \gg \sqrt{s}$. The ZEUS collaboration have used data taken between 1994 and 2006 to constrain the leptoquark Yukawa coupling for different leptoquark types and masses. Limits on the ratio between mass and Yukawa coupling range from 0.29 to 2.08 TeV. In Figure 4 indirect limits from ZEUS are compared to the H1 exclusion limits at 95% C.L. on the Yukawa coupling of $S_{0,L}$ and $\tilde{S}_{1/2,L}$ leptoquarks, as a function of their mass [6]. Limits from LEP and the Tevatron are also indicated.

4 Conclusions

Lepton beam polarization and high luminosity delivered at HERA II opened a new window for precise EW studies and searches for physics beyond SM. Measured NC DIS cross sections at high Q^2 are in very good agreement with SM, so only limits on deviations from SM could be set within different models. HERA running has finished, but analyses of large samples of data are still ongoing and more interesting results can be expected.

References

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